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Web Based Gas Turbine System Design: A Novel Framework*

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Abstract: Despite of usage of computer simulation packages in a schematic Gas turbine system design environment, limited efforts have been carried out towards the usage of web based environments for the design of some such system. This paper presents a novel framework for web based gas turbine system design. Development of web based environment for gas turbine system designs will not only nurture the sharing potential of the information among the peer user group but also design exchange updation for existing gas turbine system designs along with its sensitivity analysis through web browser. The user interface modules as the front end and the knowledge modules with servers along with schedule of information exchange have been proposed in this paper for the gas turbine system designs.
Keywords: Gas turbine system design, web based systems, expert systems, system design, Internet applications in design

1. Introduction

The gas turbine systems have almost captured the power generation global market including aviation, industrial and marine applications due to their operating flexibility, high reliability[1] and better system performance w. r. t. other prime movers like diesel engines. Technological advancements have lead to development of gas turbine designs which can operate under 1650 °C maximum cycle temperature or more and several million hours of product life cycles. Developments in the aviation technologies in the past few decades have attracted the gas turbine system designers for their valuable contributions in system design and subsystem design aspects for gas turbines. With the evolution of genetic algorithms, fuzzy reasoning, several

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complex problems related to design issues of such systems have been solved through interdisciplinary research. But, till date the Gas turbine system design is supposed to its childhood stage with several unsolved stages of the design processes due to limited involvements of interdisciplinary research and awareness of technological advancement for its peer researchers.

This paper presents a novel framework for interaction of peer user and designer groups through web based graphical user Interface. The shared information through such mechanism will not only help in increase the knowledge database for the system designers, but also develop a platform for interaction among peer researchers for catalytic technological advancements in the gas turbine system domains.

2. Related Research and Other Systems

The preliminary design of gas turbine systems[2, 3] and subsystems provide rough framework for estimating the design and process variables under system modeled constraints. Preliminary assumptions considered deviate the critical assessments of gas turbine system designs at system level as well as subsystem levels i.e. Component level. Leading gas turbine system manufacturers[4] have documented the effect of various performance parameters on the overall gas turbine system design performance. With the advent of web based applications, such systems have also been modeled[5] in terms of process parameters with interactive displays for output variables for standalone PCs. various gas turbine cycles and gas turbine engine configurations along with interactive engine selection modules[6-7] have also been developed primarily for aircraft applications also. Since, the web based frameworks have been very common in recent past for other kind of system applications i.e. material selection[8], transformer designs[9], expert systems[10], combined cycle gas turbine application[11] etc., which has motivated the peer researchers for their valuable contributions in the areas of gas turbine systems as this domain is slightly untouched from such technologies under a common sharing research platform.

This paper presents a novel framework for gas turbine system design using web browser applications. Various modules of the proposed framework for concise representation of Gas turbine systems will be discussed in detail along with their information sharing protocols.

3. Gas Turbine System Design Framework

Since the gas turbine systems have specific customers in the market, the market research team identifies the customer desires on the basis of their

specific queries. In parallel, identification of all available but useful resources is carried out which may act as information database for the conceptual designers working as a part of design management sub-system. Once, the subjective information pertaining to customer desires is nurtured by the design information subsystem through the use of conceptual design techniques and industrial design techniques, functional requirements are framed up for the gas turbine system in the form of specifications which further act as representation of the perceived quality parameters for customer desires.

The design information subsystem also identifies the alternative in-class gas turbine systems and the feasible layouts of the gas turbine systems for preliminary design considerations which may contribute to the utmost satisfaction of the customer. Since, managing of the gas turbine system design is also related to economy in terms of time and costs for the system designers with a best compromised solution for functional requirements, various design studies are carried out to ensure the operational availability. On the basis of extracted information for the materials and in-class alternative gas turbine system, thermodynamic design point studies are carried out w.r.t. the ambient and specific objectives of the application.

In the process of design analysis, the system is further evaluated for the aerodynamic performance and the mechanical design performance through a regular review of the design stages in concurrence. In parallel, the feasibility is further ensured for the off- design system desired characteristics and the control system design parameters of the gas turbine system. The design review process also ensures the equilibrium matching constraints of the test-rigs for its optimal performance within the operational envelope. Subsequently, a detailed design of the gas turbine system is prepared from manufacturability point of view up to the subcomponent level i.e. intakes, compressor modules, ducts, turbines etc.. Once, the gas turbine system is manufactured and assembled, the testing and convergence analysis of performance parameters terms as conformance to functional desires for integrated model of the gas turbine system.

On the basis of continued support by the manufacturer to the customer for usage of developed gas turbine system, the feedback is incorporated in the gas turbine system designs through its updated and up-rated versions. A systematic representation of this generic integrated framework for the gas turbine system design is represented in Figure 1.

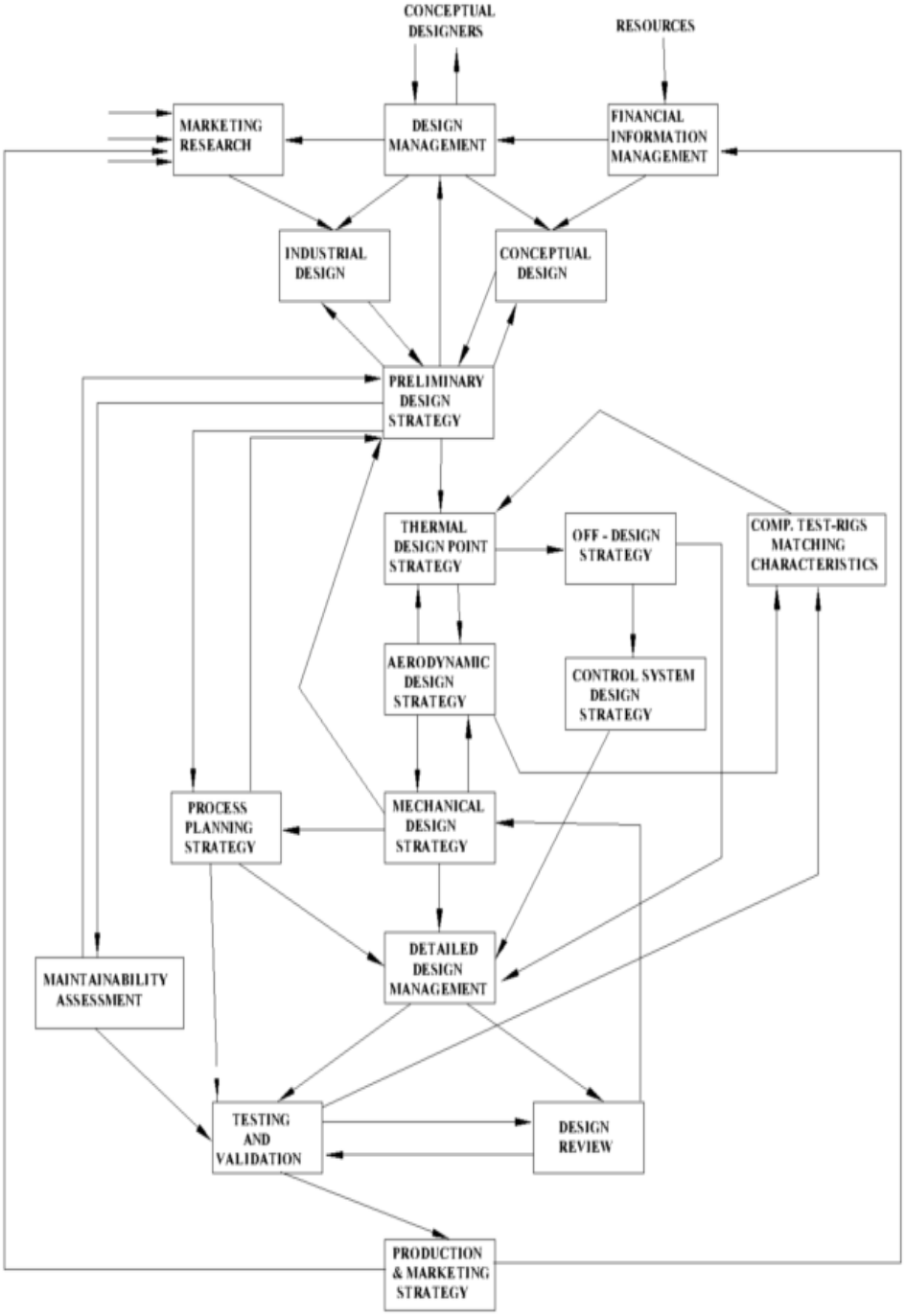

Fig. 1: Gas turbine system design framework

4. Web Based Gas Turbine System Design Architecture

The proposed system aims at selecting the optimal parameters of the gas turbine system components and selection of gas turbine system components on the basis of knowledge acquisition repository in the database. This will help the inexperienced designer to simulate the trial runs for gas turbine system design and accumulating facts as input from the expert's opinions and relational data. The inexperienced engineer will accumulate the gas turbine system design and selection expertise through usage of such proposed systems.

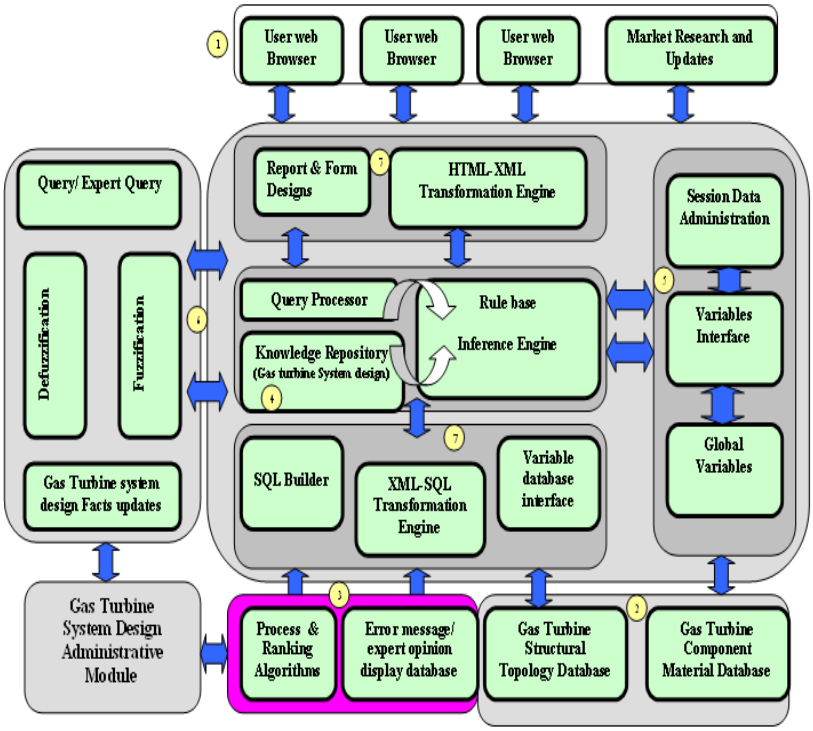

Fig. 2: Web based Gas Turbine system design Architecture

The proposed architecture has the following seven modules:
(a). Web based Graphical User Interface
(b). Gas turbine system selection Module
(c). Gas Turbine system preference module
(d). knowledge repository
(e). Gas turbine system performance prediction module
(f). Interaction or Query module

(g). Gas Turbine System Interface Modules

All the information and associated programs of the Gas Turbine system design are placed on the web server. The user can access the gas turbine system design environment using a web browser through the link at specified URL. The various segments of the Gas Turbine System design architecture are represented in Figure 2.

5. System Implementation

This section deals with the implementation details of the proposed framework. The proposed novel framework works under dynamic environment protocol which activates with the registration of the user and knowledge domain for generating access oriented paths for the user for interactive modules and knowledge repository. The various segments of the novel framework are described as below:

5.1 Web based Graphics User Interface (WBGUI)

For the proposed system, we require more than 500 HTML objects and form controls which also include text boxes for interaction with the user. These text boxes are to be used for representing the input and output functional values, pop-up massages and error massages, labels for text boxes, option group menus and the graphs etc. The user can access the information and the modules as per hierarchy of the links or functions provided in the menus. The label of the query by the user opens the respective window of the module. Some of the main GUI features incorporated in the web based gas turbine system are numbered and boxed areas for entry of related data in sub-steps. Input and output boxes are colour coded according to whether the entry provided by the user is complete, requisite or not accessible through GUI. Scroll bars for viewing large tables, figures and plots in window and the pop-up massages windows for suggestions and errors.

5.2 Gas Turbine System Selection Module

The information received from the user may consist of measurable and immeasurable quantities. Since, the user interacts with the system with perceptions and judgments with little knowledge base, the linguistic mode of representations for interaction with the user are most suitable. However, some of the measurable data or crisp values received from the user are also converted into linguistic or fuzzy modes of representation for consistency in processing of the information with the user as well as the processor..

In the gas turbine system selection module, the preliminary system design selections including applications are selected. For example, for a typical Gas turbine application, number of spools, type of compressors and gas turbines etc are to be selected through this module. The knowledge repository for this module is in the form of rule base which appear in natural way as expert opinions for design of such systems.
The CLIPs are used to implement the inference function and explanation facility. These CLIPS are generally coded in Visual C++ or JAVA programming language to have an easy interface with the web browser.

5.3 Gas Turbine System Preference Module

Upon the query raised by the user for a given desired input, the query is processed in the gas turbine system database where more than one candidate gas turbine system modules are present. For the given set of input variables, both linguistic and crisp variables, the preference of the gas turbine systems is generally executed through Multi-Criteria decision making algorithms provided in the gas turbine system database. The preferential order or the ranking of suitable gas turbine systems already stored in the database involves the following steps:

- Normalize the decision matrix obtained as the user defined variables as per preference module input interface may have different units of measurements.
- Assign the weights to the attributes as per reasoning trail accessible from knowledge repository through inference module.
- Calculate the degree of closeness for each candidate gas turbine system to hypothetical +ve benchmark solutions and arrange the gas turbine systems in the descending order of degree of closeness mentioned above. Since, in case of gas turbine systems most of the data is interval based, therefore interval based MADM approach has been adopted for developing the code for ranking the gas turbine systems as displayed to the user in output text box through web browser.

5.4 Gas Turbine system Knowledge Repository

An expert knowledge is provided for the gas turbine systems where the knowledge facts and process algorithms are stored. The facts related to system integration along with structural topology are stored in system knowledge database. Structural hierarchy links are activated for the subcomponents of the gas turbine systems such as compressor, combustors and turbines along with free turbine units.

Structural hierarchy details for the support integration units such as ventilation & enclosure unit, cooling system, lubrication system, atomizing

unit, fueling system etc are provided with separate links accessible by the web browser. The structural topology at the component level is associated with their material database and the functional relationship database. The material database is inherited with material selection topology along with material property selection module and material property matrices for the materials. New materials may be added in the database along with its material properties. Addition of new facts and functional relationships will enrich the knowledge repository.

5.5 Gas Turbine System Performance Prediction Module

Entire material property database and the component level functional relationship database are mutually interacting with search and solution algorithms to produce the output for matching the facts with knowledge repository so that information or response may be sent to the user through response text box in GUI through web browser. The output in the form of graphs, Plots in compatible exchange format can be received by the user for user defined inputs through the system performance module only. A prerecorded set of outputs for an optimal set of user defined inputs for an hypothetically benchmarked solution is also displayed to the user through the same response text box so that user can analyze the designed system performance for better system design features.

5.6 Gas Turbine System Query Module

This module is set to bear the flexibility in the input ranges for the user defined set of design variables. The user makes the query through this module with desired set of inputs through web based Graphics User Interface. The query antecedents are fuzzified to get the relational match with the rules already existing in the knowledge repository. If the rule exists in the database, the subsequent part of the rule is defuzzified and reported to the user in response display text box. In case, the rule or knowledge related to query is not present in the database, the new user defined rules are stored in the database through administrative approval for send the new rules to knowledge repository.

5.7 Gas Turbine System Interface Module

This module is considered to be the heart of the gas turbine system design environment. All the information exchange from the user to the server based gas turbine system design environment or module or vice- versa are processed through this module. This module filters the information as per accessibility mode of interpretation and finally reporting in the form of user defined outputs.

6. Discussion

The proposed Web based Gas turbine system design novel framework consider the structural topology of the gas turbine systems including the knowledge repository for material properties and well established facts for Gas turbine system. From the web browser user interface, the user can access the system selection module with sub-access to system components, their materials and behavioural relationships. The user can put up a query on the basis of facts and system variable operating ranges. The query will be decoded through user interface and will be decoded to match with the existing knowledge (established rules) lying in the repository. The genetic algorithm based search selection procedures are to be adopted for matching the query variables and its string to established fact strings. The fuzzification and the de-fuzzification of the query variables are a part of fact matching procedures. The new query and discussions are stored in the session databases for further access to server administrator for accepting and knowledge acquisition and establishing the matching relationships for the query string variables with the memory string database. Since, the framework comprises of behavioural relationships for the system components in terms of global system variables, the proposed framework can act as web based expert system novel framework for gas turbine system design and analysis.

7. Conclusion

In this paper, a web based Gas Turbine system design framework has been put forward. The proposed architecture can meet the demand of gas turbine system designers for accessing the expert knowledge and updating the same with further knowledge acquisition in the form of behavioural relationships and the facts i.e. rules for the gas turbine system designs. Since, the design of gas turbine systems for its optimal solutions and designs, is an endless task, the proposed framework will provide a platform for sharing the world wide information for the research domains and knowledge of Gas turbine system designs for multi-dimensional growth in the areas of Gas turbine system designs.

Since, new materials are depleting the earlier conventionally used materials for gas turbine system components, the material database can be accessed through web browser and the user can assign weights for the materials and new properties which makes the researcher convenient to work and analyze for gas turbine process simulations and modifications. Therefore, the proposed novel framework for the gas turbine systems can be

a value aided tool in comparison to conventional gas turbine system design processes and will catalyze the development and contributions of Gas turbines in the emerging energy and service sectors.

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